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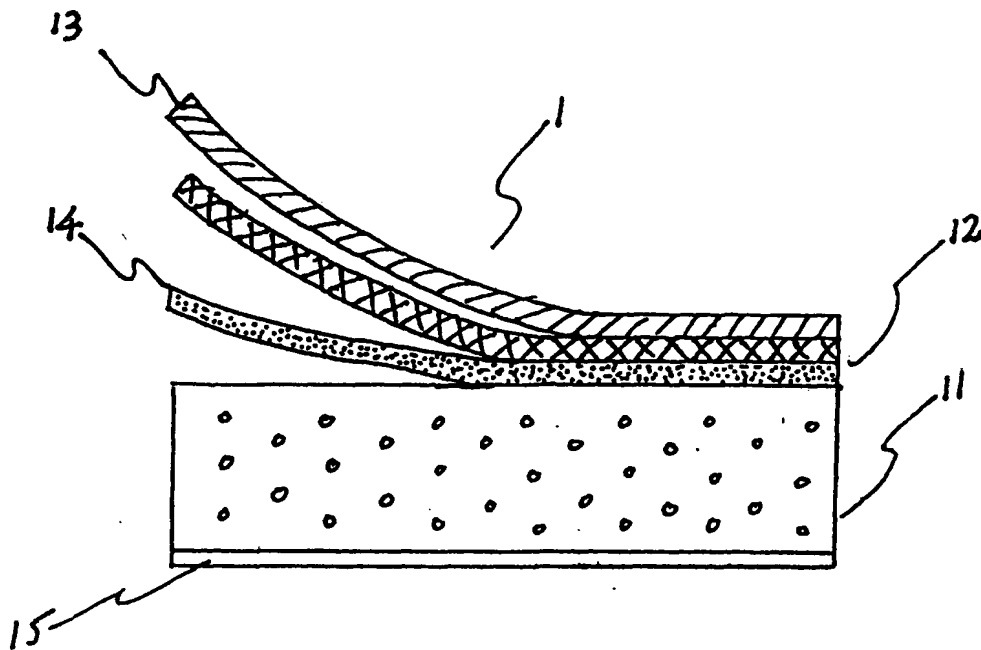
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(54) Title: ACOUSTIC TILE AND ITS USE IN VEHICLE SOUND PROOFING



(57) Abstract: An acoustic tile for damping vibration in a vehicle body panel, comprises a base layer (11) comprising a closed cell synthetic elastomeric foam bonded on one surface to a dense, stiff, non-cellular constraining layer (12). The base layer (11) preferably comprises nitril rubber foam and the constraining layer preferable comprises an elastomeric/plastomeric polymer-bitu-
men blend.



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ACOUSTIC TILE AND ITS USE IN VEHICLE SOUND PROOFING

The present invention relates to an acoustic tile, especially to an acoustic tile for use in vehicle sound proofing by damping vibration in a vehicle body panel.

5

BACKGROUND TO THE INVENTION

Noise inside a motor vehicle arises from various sources. External sources include rain and wind impacting on the vehicle body panels and internal
10 sources include the engine of the vehicle. Vibration of the body panels, such as the bonnet and the roof and door panels, is the source of considerable noise inside the vehicle.

Attempts have been made to damp vibration of the body panels and hence
15 reduce the noise inside the vehicle, by attaching layers of damping material to the surfaces of the panels.

One traditional method has been to attach press-formed fibrous composite sheets. However, the press-formed fibrous composite sheets are prone to
20 rotting when damp, as the material is not water resistant. They are very difficult to clean, being especially prone to trapping dirt, and abrasive handling will cause a measure of material disintegration.

More recently synthetic materials, and especially visco-elastic materials, have
25 been used. One such material is a co-polymer comprising ethylene, vinyl acetate and acrylic and/or methacrylic acid.

Another proposal has been to apply a visco-elastic adhesive composition comprising a polyepoxide, a polyether amine, a hetrocrylic amine and a
30 phenol, which is said to be useful as a damping material over a temperature range of -25°C to +60°C.

A yet further proposal has been to use composite sheets comprising an

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elastomeric butyl polymer sheet bonded to a thin layer of non-elastomeric material on the surface that is to be positioned away from the panel.

5 The various materials hitherto proposed as damping materials, while providing a degree of damping are not particularly effective and do not provide the required light weight, high performance systems that are desired in this technological age. They add considerably to the effective weight of the panel and thus detract from the overall performance of the vehicle. Furthermore they are not particularly useful in preventing transmission of noise from other
10 sources.

Improved materials that will not only effectively damp the vibration of the body panels but will also reduce sound transmission through the body panels would be a great advance in the art of vehicle sound proofing.

15

SUMMARY OF THE INVENTION

According to the invention an acoustic tile for damping vibration in a vehicle body panel, comprises a base layer comprising a closed cell synthetic
20 elastomeric foam bonded on one surface to a dense, stiff, non-cellular constraining layer.

The acoustic tile of the invention is a multi-layer sound and vibration-reducing overlay that can be applied to the doors, mudguards, roof, engine
25 compartment bulkhead and other body panels of a vehicle.

The acoustic tile of the invention can be attached to the body panels by any desired means but for greatest efficiency the tiles should be held tight against the panel. Thus they are preferably adhesively adhered to the panels.
30 Preferably the tiles have a layer of pressure sensitive adhesive on the surface opposite the constraining layer.

The surface of the constraining layer may be patterned or textured or the

constraining layer may include a covering or protecting layer, which may be patterned or textured. The constraining layer may include a reinforcing layer between the constraining layer and any covering or protecting layer. Preferably the constraining layer and any covering or protecting layer and any
5 reinforcing layer form a single composite structure.

Unlike most currently used methods of noise and vibration reducing techniques employed in motor vehicles, the acoustic tile of the invention uses noise and vibration cancellation principles. The constraining layer may be
10 compared to a weight on a spring attached to the body panel. The vibrations in the panel are transmitted to the foam layer, which tries to transmit them to the constraining layer. Since the constraining layer is stiffer and more massive than the foam layer it does not move so readily and hence the energy of the vibration is converted from kinetic energy to potential energy and heat
15 and hence the vibration is damped and its frequency reduced to more tolerable levels.

The elastomeric foam layer should be sufficiently flexible that it can readily conform to the contours of the body panels and is preferably a polyurethane
20 foam, a polyethylene foam or a nitrile rubber foam. The thickness of the foam layer is preferably between 3 mm and 15 mm but is more preferably about 6 mm.

The foam preferably has a density between 10 and 140 kg/m³, more preferably
25 between 60 kg/m³ and 140 kg/m³ and a modulus of elasticity between 4×10^7 N/m² and 8×10^7 N/m². It should also have reasonable tear strength and be fire retardant or self-extinguishing. In addition it should be resistant to UV, ozone, mildew and fungus normal motor vehicle fluids.

30 Preferably a 6mm layer having an area of 200 mm x 120 mm has a compliance between 1×10^{-9} and 10×10^{-9} m/N, preferably between 2×10^{-9} and 6×10^{-9} m/N.

The constraining layer simply adds mass to the system and may be a layer of any material that ensures that the moment of inertia of the layer is such it will not move readily when the foam layer is vibrated by the vibrations in the panel to which the tile is attached. The constraining layer although stiffer than the
5 foam layer must not be so stiff that the tile cannot be conformed to the contours of the body panels. It should also have high tear and puncture resistance.

The thickness of the constraining layer is preferably between 1 mm and 15
10 mm and will usually be about 3 mm.

The material of the constraining layer preferably has a density between 200 kg/m³ and 500 kg/m³, more preferably between 300 kg/m³ and 375 kg/m³

15 The mass ratio of the constraining layer to the foam layer is preferably from 2:1 to 10:1, more preferably from 5:1 to 7:1.

Because of the manner in which the acoustic tile of the invention operates, it only requires a few small pieces of tile on any given body panel to make a
20 dramatic difference to the vibration characteristics of the panel.

Thus, by simply attaching conveniently sized pieces of the acoustic tile onto at least some of the body panels in a vehicle, noise from panel vibration and other sources can be reduced significantly. With the acoustic tile installed, the
25 noise inside a vehicle can be reduced to levels that greatly enhance driving comfort and enjoyment.

Since the entire surface of a body panel does not have to be covered with tile, it is preferred that the individual tiles are produced such that each tile is in two
30 parts with interlocking fingers so that the area of coverage of the tile can be increased by drawing the two parts apart while retaining contact between at least the ends of the fingers. By forming the tiles in this way a big saving in packaging size can also be obtained.

Because of the closed cell structure of the foam layer, in addition to the vibration noise being reduced or having its frequency altered, the tiles also effectively suppress structural, engine and road noise transmitted through the body panels to which they are attached. Heat transfer through the body panels is also reduced.

DESCRIPTION OF PREFERRED EMBODIMENTS

The invention will now be described in greater detail, by way of example, with reference to the accompanying drawings in which:

Fig. 1 is a section through an acoustic tile according to one embodiment of the invention;

Fig. 2 is a plan view of a preferred form of the tile shown in Fig. 1

Fig. 3 shows one way in which the acoustic tiles can be applied to vehicle body panels.

Fig. 4 is a graph showing typical performance characteristics of a vehicle body panel fitted with the acoustic tile.

Referring now to Fig. 1, the acoustic tile 1 comprises a base layer 11 of closed cell fire retardant nitril rubber and a constraining layer 12 of a phase inverted distilled bitumen compound, the continuous phase of which is formed of elastomeric and plastomeric polymers in which the bitumen is dispersed, a reinforcing layer 13 of a composite, high weight, rot-proof, non-woven polyester fabric, stabilized with fiberglass mat and a protective layer 14 of embossed polyethylene. Although the layers 12, 13 and 14 are shown in the drawing as separate layers the three layers, in practice is a composite structure.

Base layer 11 is 6 mm thick. The nitril foam has a density of 100 kg/m^3 , a modulus of elasticity of $7.6 \times 10^7 \text{ N/m}^2$, a compliance of $3.3 \times 10^{-9} \text{ m/N}$ for an area of 200 mm x 120mm and a tear strength of 2445 N/m

- 5 Constraining layer 12, together with layers 13 and 14, is 3 mm thick. The composite structure of layers 12, 13 and 14 has a density of 370 kg/m^3 .

10 With these characteristics, a tile of size approximately 200 mm x 120 mm, which is a convenient size both for packing and for application, has a weight of approximately 110 grams so that the application of 36 tiles, which is more than adequate for the average motor car, will only result in a weight increase of about 4 kilograms.

15 On its opposite surface tile 1 has a layer 15 of pressure sensitive adhesive.

Referring now to Fig. 2, tile 1 is pre-cut during manufacture to give two equal sized pieces 2 and 3 with interlocking fingers 4 and 5, respectively. By pulling pieces 2 and 3 apart, while retaining fingers 4 and 5 in contact, preferably over at least 3 cm of the length of the fingers, the effective length and coverage of a tile 1 can be greatly increased. Fingers 4 and 5 will be fully engaged for packaging.

25 As shown in Fig. 3, to be effective the tiles do not have to be applied over the entire surface of a body panel of a vehicle. A number of tiles, as shown in Fig. 2 can be spaced over the surface of any desired body panel.

30 With reference to Fig. 4, a series of tests were carried out to measure the effectiveness of the acoustic tile of the invention by comparing the acoustic characteristics of an undamped metal panel with those of the same metal panel to which a single tile of the type shown in Fig. 2 has been applied. The plate was 0.25 mm thick, 45.7 cm wide and 48.3 cm long. The tile had an area of 200 mm x 120 mm and was expanded by drawing the two pieces

apart until 30 mm of the fingers 4, 5 remained overlapping giving a coverage area of 397 mm x 200 mm. The plate thus has an area approximately 9 times the area covered by the tile.

- 5 The metal panel was mounted onto the open end of a medium density fiberboard box 45.7 cm x 48.3 cm x 50.8 cm with a thickness of 12 mm and was securely attached on all four edges to the box. An audio source generating a 50 Hz sinusoidal signal is placed inside the box to generate an audio signal to cause the metal panel to vibrate. The resulting panel
10 vibrations cover the full spectrum (20Hz to 20,000Hz) audible to the human ear.

- A calibrated microphone was centrally positioned 3 cm above the metal plate to record near field sound pressure levels. The acoustic signature and
15 reverberation strength of the panel with and without the expanded acoustic tile attached were captured by measuring the frequency spectrum from 20 Hz to 4,000 Hz. The resulting data recorded are an average figure obtained from 100 sampling runs. The results are depicted graphically in FIG. 4.

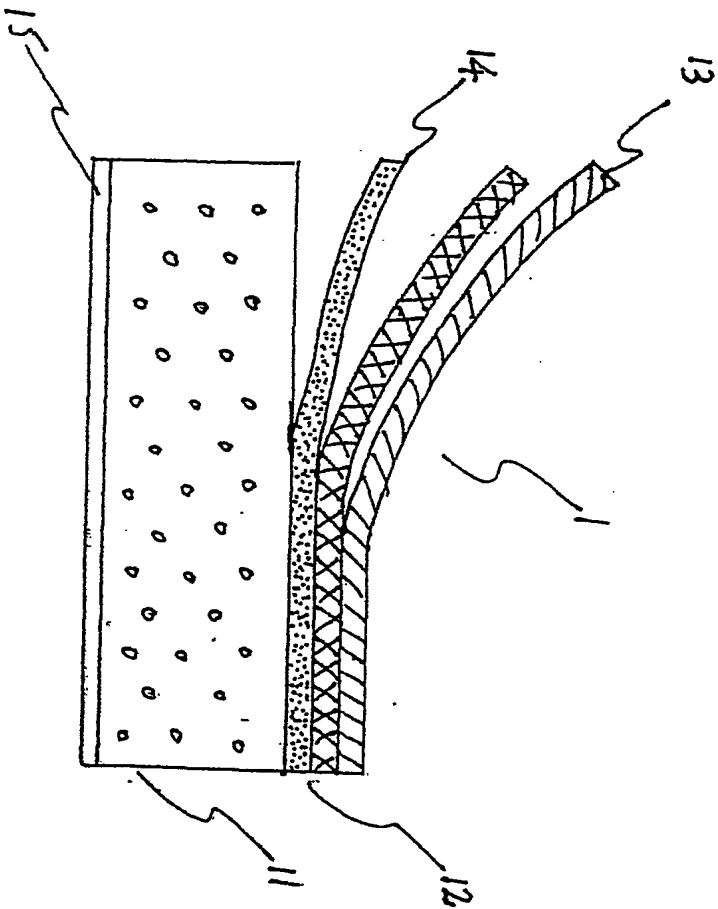
- 20 From the results obtained, the acoustic tile has significantly suppressed manifested panel frequencies from 50 Hz onwards with the region between 80 Hz to 3150 Hz registering the most impressive suppression. In this region, reductions in excess of 40 dB are registered in some areas; this represents an energy level drop of more than 10000 times between a panel without an
25 acoustic tile and one that has the acoustic tile attached. Since the decibel scale is logarithmic a 40 dB reduction therefore corresponds to a reduction in perceived volume of sixteen times the reference audible volume.

CLAIMS

- 1 An acoustic tile for damping vibration in a vehicle body panel, comprising
a base layer (11) comprising a closed cell synthetic elastomeric foam
5 bonded on one surface to a dense, stiff, non-cellular constraining layer
(12).
- 2 An acoustic tile according to claim 1 wherein foam of the base layer (11)
has a density between 10 kg/m^3 and 140 kg/m^3 and a modulus of elasticity
10 between 4×10^7 and $8 \times 10^7 \text{ N/m}^2$.
- 3 An acoustic tile according claim 1 or claim 2, wherein the thickness of the
base layer (11) is between 3 mm and 15 mm.
- 15 4 An acoustic tile according to claim 3, wherein the thickness of the base
layer (11) is about 6 mm.
- 5 An acoustic tile according to any one of claims 1 to 4, wherein the base
layer (11) comprises closed cell polyurethane foam, closed cell
20 polyethylene foam or closed cell nitrile rubber foam.
- 6 An acoustic tile according to any one of claims 1 to 5, wherein the
thickness of the constraining layer (12) is between 1 and 5 mm.
- 25 7 An acoustic tile according to claim 6, wherein the thickness of the
constraining layer (13) is about 3 mm.
- 8 An acoustic tile according to any one of claims 1 to 7, wherein the material
of the constraining layer (13) has a density between 200 kg/m^3 and 400
30 kg/m^3 ,
- 9 An acoustic tile according to claim 8, wherein the material of the
constraining layer (13) has a density between 300 kg/m^3 and 375 kg/m^3

- 10 An acoustic tile according to any one of claims 1 to 9, wherein the
constraining layer (12) comprises bitumen.
- 5 11 An acoustic tile according to claim 10, wherein the constraining layer (12)
comprises a bitumen-polymer blend.
- 12 An acoustic tile according to any one of claims 1 to 11, wherein the
constraining layer (12) includes a protective layer (13).
- 10 13 An acoustic tile according to claim 12, wherein the protective layer (13)
comprises embossed polyethylene film.
- 14 An acoustic tile according to any one of claims 1 to 13, wherein
15 constraining layer (12) includes a reinforcing layer (14).
- 15 An acoustic tile according to claim 14, wherein the reinforcement layer
(14) comprises non-woven polyester fibre.
- 20 16 An acoustic tile according to any one of claims 12 to 15, wherein the
constraining layer (12), the protective layer (13) and/or the reinforcing layer
(14) form an integral structure.
- 25 17 An acoustic tile according to any one of claims 1 to 16, wherein the tile is
formed in two parts (2,3) with interlocking fingers (4,5) so that the area of
coverage of the tile can be increased by drawing the two parts apart while
retaining contact between at least the ends of the fingers.
- 30 18 A method of damping vibration in a body panel of a motor vehicle, which
comprises applying to the surface of the panel at least one acoustic tile
according to any one of claims 1 to 17.

FIG. 1



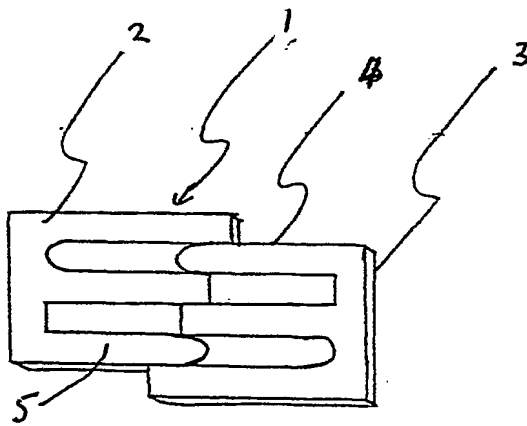


FIG. 2

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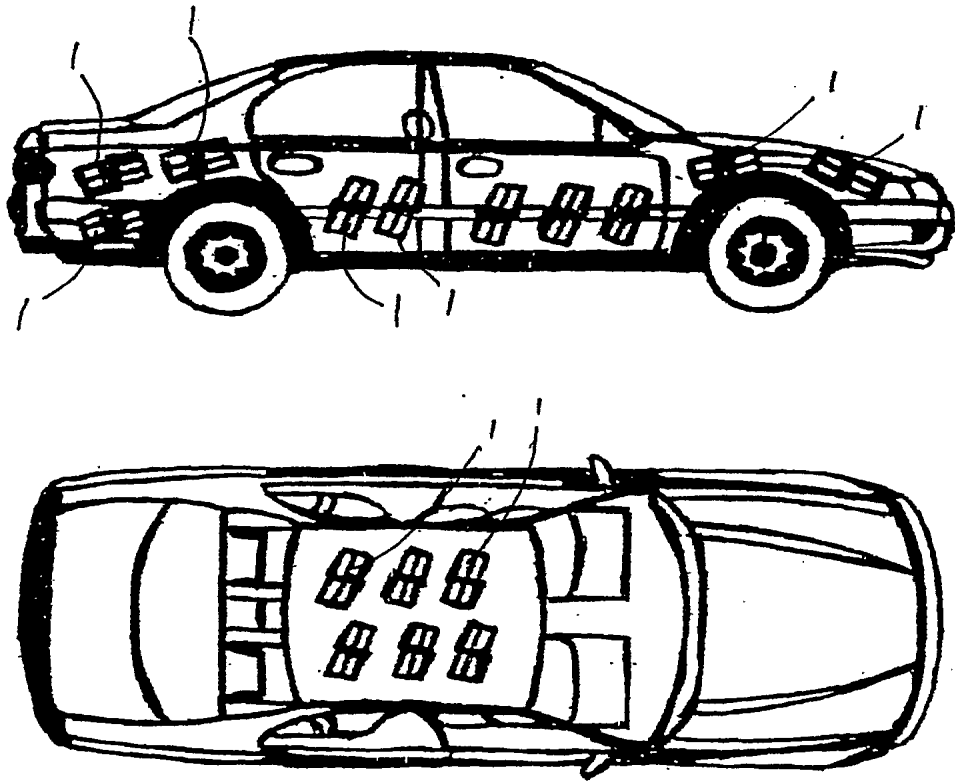


FIG. 3

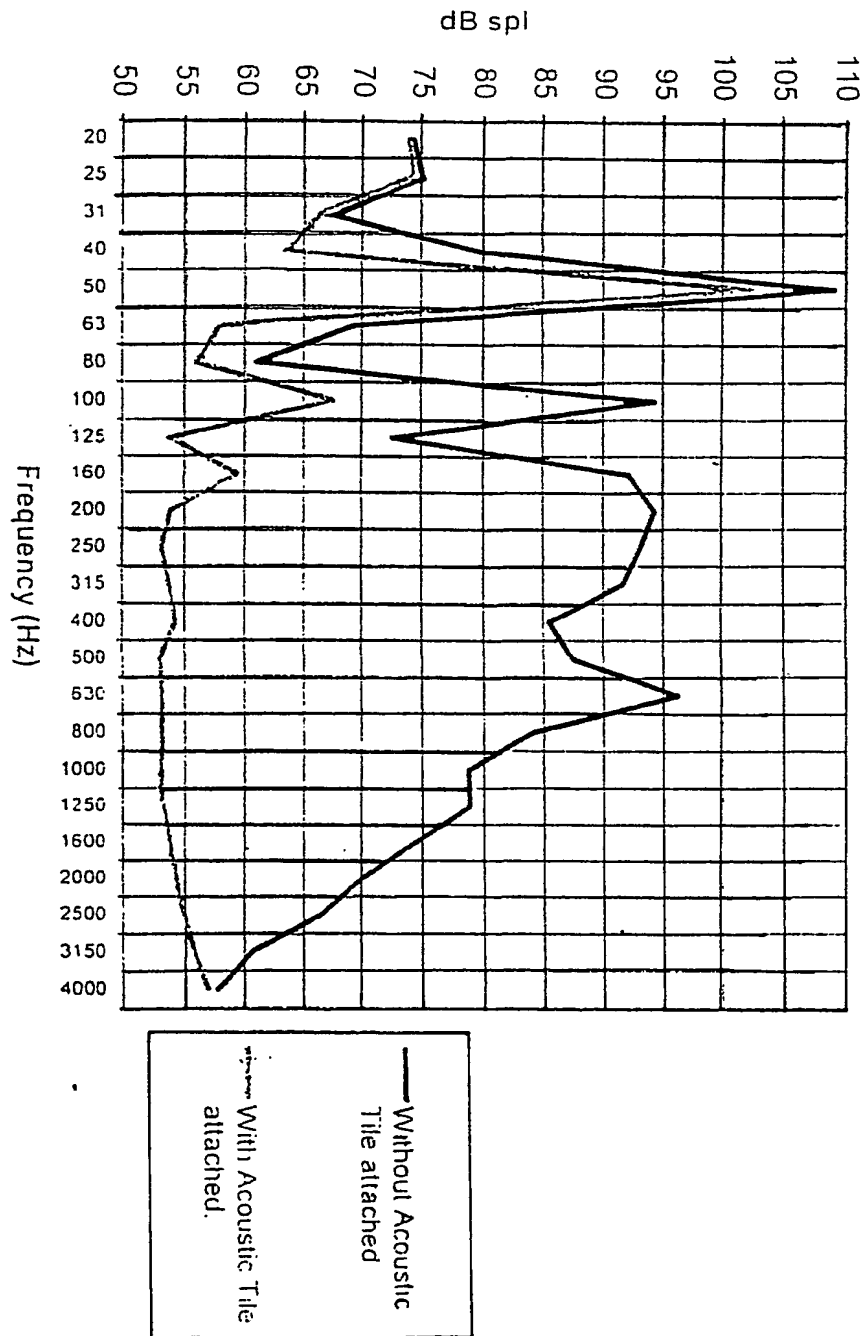


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

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A. CLASSIFICATION OF SUBJECT MATTERInt. Cl. ⁷: B60R 13/08, G10K 11/168, 11/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC⁷ AS ABOVE

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DERWENT WPAT: IPC⁷ as above and Acoustic or sound or vibrat+ or polyurethan+ or polyethylen+ or nitrile rubber or elastomeric+**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|--|-----------------------|
| X | EP 63715 A1 (Nissan Motor Company Limited) 3 November 1982 Whole Document | 1 |
| A | EP 466513 A2 (Nihon Sekiso KKK) 15 January 1992 Whole Document | |
| A | Derwent Abstract Accession No. 92-169157/21, Class P27, FR 2667430 A3 (Chem Werk Weinsheim GmbH) 3 April 1992 Abstract | |

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